EBG STRUCTURES AS PMC SIDEWALLS IN PARALLEL PLATE SLOT ANTENNAS

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Abstract- Electromagnetic BandGap (EBG) structures have unique properties in controlling the propagation of electromagnetic waves, which enable them to be implemented in a number of applications. In this work we analyse the effect of EBG sidewalls, first in a parallel plate waveguide and as practical application in parallel plate slot antennas. These structures present some interesting properties that may overcome some of the problems of conventional technologies. Recently, several EBG structures have been proposed and demonstrated to be useful in enhancing performances of microwave circuits or antennas. We use these novel structures to realize a perfect magnetic conductor (PMC) surface artificially. The results of the effect using PMC in comparison with perfect electric conductor (PEC) in the sidewalls of the parallel plate slot antennas is presented as examples of application. Using PMC sidewalls in this kind of antennas, relatively uniform field distributions are improved, so it allows to increase the directivity to enhance the efficiency of these antennas.

I. INTRODUCTION

The Electromagnetic bandgap (EBG) structures are novel periodic structures that, by generating a bandgap, can properly control the propagation of electromagnetic waves. These structures can be one, two or three dimensional periodic structures and they have been investigated for their versatility in controlling the propagation of electromagnetic waves in one, two or three dimensions. EBG technology presents some interesting properties that may overcome some of the problems of conventional technologies. In particular, recently, several EBG structures have been proposed and demonstrated to be useful in enhancing performances of microwave circuits or antennas. For example, the problem of the non-uniform field distributions in a parallel plate waveguide with perfect electric conductor (PEC) sidewalls can be prevented using perfect magnetic conductor (PMC) sidewalls. To date, PMC surfaces are receiving more and more attention since they offer advantages that cannot be accomplished by utilizing traditional PEC. In contrast to the realization of a PEC, which is not difficult in practical situations, the realization of a PMC remains a difficult task.
The difficulty stems from the fact that no conventional material has been found which can be used as a PMC because it does not exist in nature. Hence, the analysis and design of a PMC is important. One possibility to design an artificial PMC is to use periodic structures [1].
The purpose of this work is twofold: first, to provide further knowledge on the functioning of artificial PMCs by designing and analysing them, and second, to present the practical applications of PMC sidewalls in parallel plate slot antennas. The aim is to uniform the field distributions using PMC sidewalls in comparison with the PEC ones in a parallel plate waveguide and in parallel plate slot antennas.
For the design of the artificial PMC based on [1,2,3], where are presented the possibility to create a PMC surface with a novel 2D uniplanar EBG structure, we are going to analyse an array of closely spaced patches.
These planar periodic EBG structures are particularly attractive and have been intensively investigated due to their advantage of being simple, low cost and can be easily fabricated using any standard planar process without the need for vias, which are necessary for other types of EBG structures. With the aim to check the ideas exposed before, 3D electromagnetic simulations based on Finite Integral Time Domain (FITD) have been achieved with the software CST Microwave Studio v. 4.0.
As a practical example, EBG sidewalls acting as PMC are going to be analysed in parallel plate slot antennas as described in [4,5]. A most uniformity of the field distributions inside this kind of antennas allows us to increase the directivity, getting to enhance the efficiency of these antennas. These practical applications will allow us to validate the simulation results.

II. DESIGN OF THE PMC WITH EBG

The main difference in electrical property between a perfect electric conductor (PEC) and perfect magnetic conductor (PMC) can be observed by measuring the reflection coefficient. The magnitude of the reflection coefficient for both cases is equal to 1, while the phase differs by 180°.

As can be seen in Fig.1, in this work a 2D uniplanar EBG structure is employed to realize the PMC surface [3].

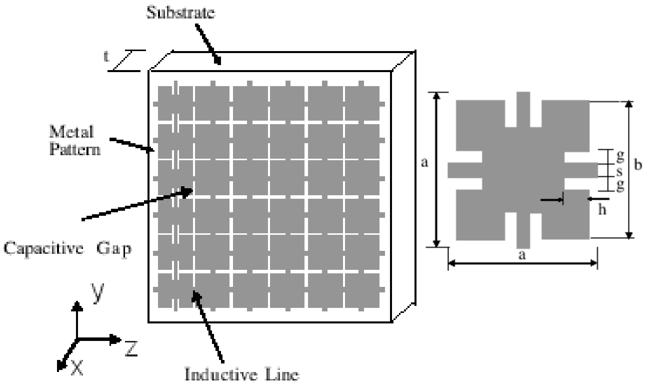

Fig. 1. 2D uniplanar EBG structure acting as PMC.

Alternatively, the conducting surface acts as an open circuit in the case of a PMC, and conversely as a short circuit in the case of a PEC. One way to present these short and open conditions is by using a periodic pattern. Each element of the periodic pattern provides an equivalent L and C parallel connection, which changes the surface impedance. At frequencies where the periodic loading presents an open circuit condition, a PMC surface is created. The basic idea here is the introduction of a periodic network of LC elements to shorten the wavelength of the propagation wave. These PMC surfaces show interesting properties.

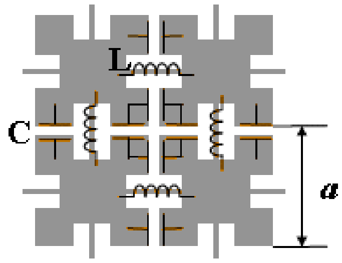

Fig. 2. Circuit scheme of the EBG periodic structures.

To understand the performance of the planar PMC structures, it is suitable to investigate as a test structure a periodic array of closely spaced patches as shown in Fig. 3.

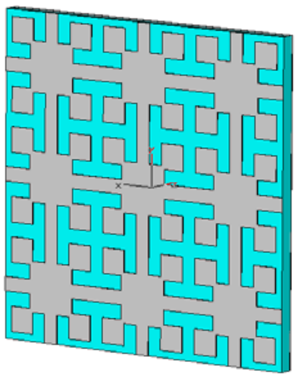

Fig. 3. Simulated 2D uniplanar EBG structures.

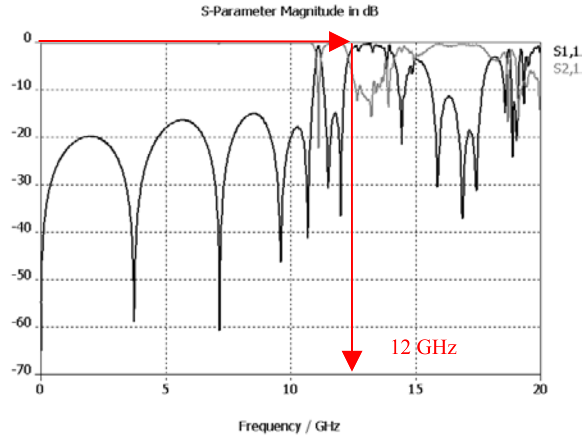

Fig. 4. Simulated S-parameters of a normallly incident plane wave on the 2D uniplanar EBG surface.

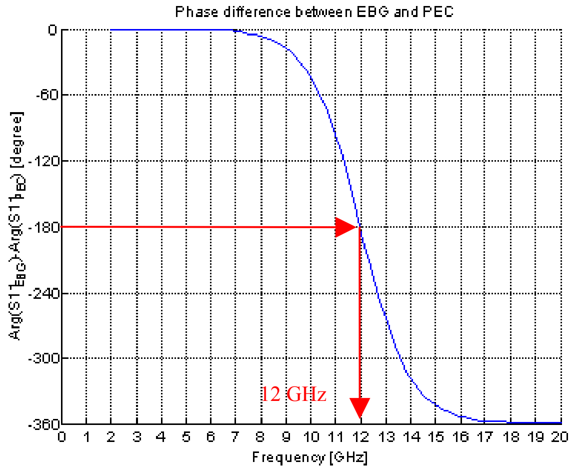

Fig. 5. Simulated phase difference of the reflection coefficient between the EBG surface and PEC surface.

Fig. 4 and Fig.5 show the S-parameters and the phase difference when the simulated EBG surface is impinged upon by a normally incident plane wave. The optimum operating point is 11.9 GHz, where a 180° phase difference in reflection coefficient between EBG and PEC surfaces occurs. It corresponds to the operating frequency where the EBG structure behave like a PMC surface.

III. ANALYSIS OF A PARALLEL PLATE WAVEGUIDE

The prototype of the waveguide that we analysed is a rectangular parallel plate waveguide of 330mm x 318mm with sidewalls, between that we had a foam dielectric of 7.5mm height as shown in Fig. 6. The operating frequency of this waveguide is 11.92 GHz. The ideal functioning of the waveguide only propagates a TEM mode (or quasi TEM). A rectangular waveguide-fed feed slots excite the parallel plate waveguide to generate a TEM mode. A common characteristic to the propagation of this kind of mode is its degradation at the same time as we move away from the feed point, that causes non-uniform field distributions in the waveguide with PEC sidewalls.

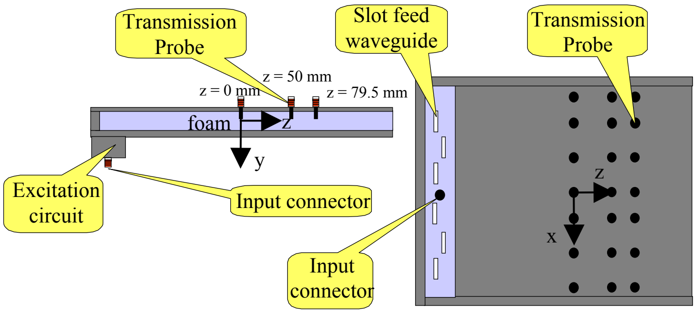

Fig. 6. Scheme of the parallel plate waveguide.

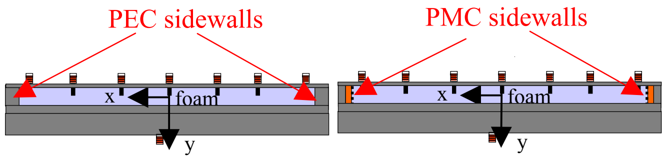

Fig. 7. Scheme of the profile parallel plate waveguide with PEC and PMC sidewalls.

Fig. 8 shows the prototype of the 2D uniplanar EBG structure acting as PMC sidewalls :

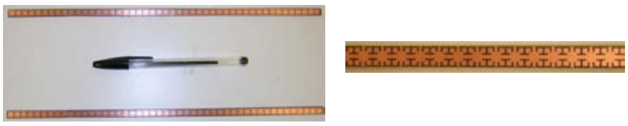

Fig. 8. Prototype of the EBG strcutures acting as PMC sidewalls

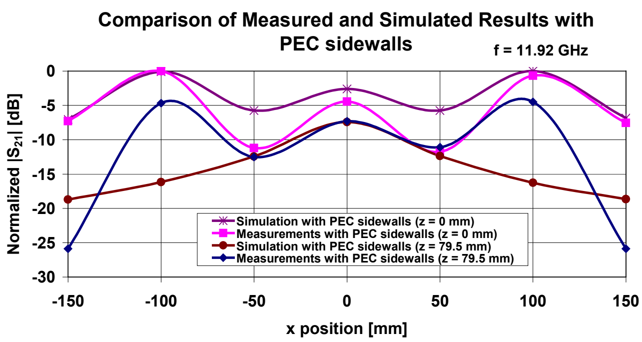

Fig. 9. Simulated and measured transmission coefficients between the input connector and the transmission probes.

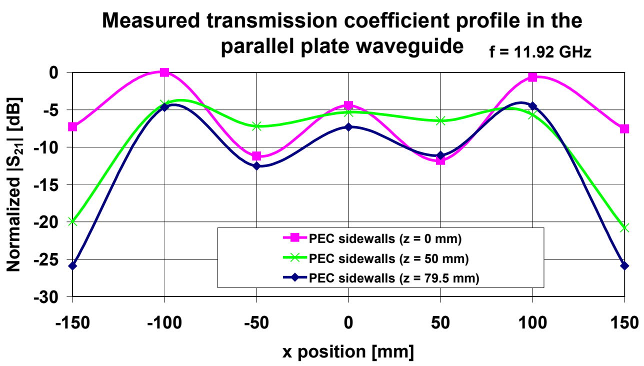

Fig. 10. Measured transmission coefficients between the input connector and the transmission probes with PEC sidewalls.

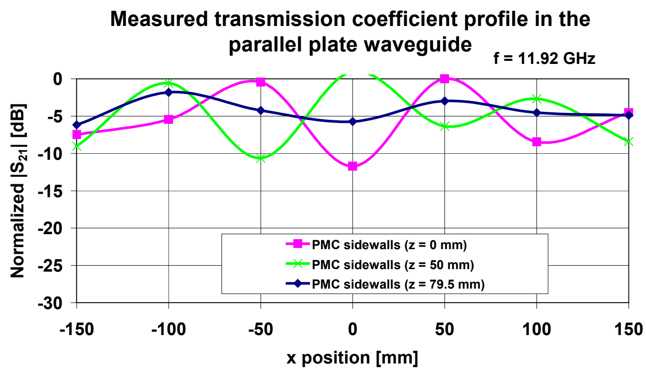

Fig. 11. Measured transmission coefficients between the input connector and the transmission probes with PMC sidewalls.

In Fig. 7, the disposition of the EBG structure in the parallel plate waveguide is shown.

The field profile distributions in the parallel plate waveguide with PEC and PMC sidewalls have been simulated and measured at the frequency of 11.92 GHz.

Fig. 9 shows the comparison of the simulated and the experimental results of the transmission coefficients in the parallel plate waveguide with PEC sidewalls. Good agreement between the simulations and the measurements are observed.

The ripples that can be seen in the results are due to that the TEM wave has been generated with the array of slot in the feed waveguide. These ripples tend to be smooth at the same time as we move away from the rectangular waveguide-fed feed slots in the parallel plate waveguide.

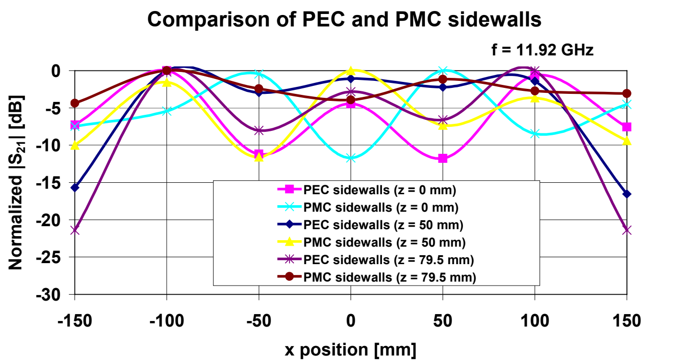

Fig. 12. Comparison of the measured transmission coefficients in the parallel plate waveguide with PEC and PMC sidewalls.

As can be seen in Fig. 12, the PMC sidewalls waveguide has a relatively uniform field distribution compared to the standard waveguide with PEC sidewalls.

One thing that should be pointed out here is that the peak value of the field in the PMC sidewalls waveguide is lower than that in the PEC sidewalls waveguide due to the field flattening.

IV. PRACTICAL APPLICATION

The proposed 2D uniplanar EBG structure acting as PMC is applied in parallel plate slot antennas with linear polarization shown in Fig. 13 and Fig. 14 [7,8], which operating frequency is 12 GHz.
This kind of antennas is a rectangular parallel plate waveguide excited by rectangular waveguide-fed slots as shown in Fig. 13 [10] or by a excitation circuit of an array of patches in microstrip planar technology as shown in Fig. 14. These excitations generate a TEM plane wave that propagates in the perpendicular direction of the axis of the parallel plate waveguide. This plane wave excites the radiating structure that consists of a planar array of resonant slots in the upper plate of the waveguide.

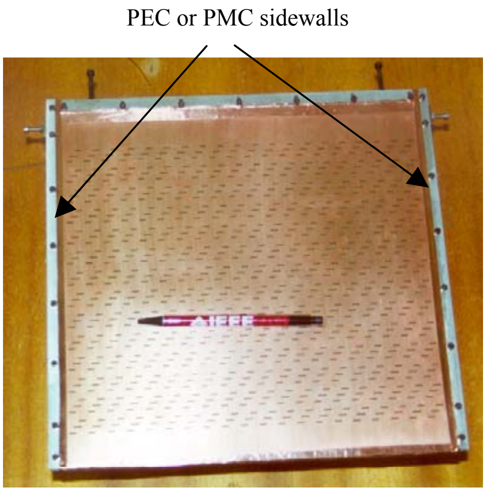

Fig. 13. Parallel plate slot antenna with linear polarization excited by rectangular waveguide.

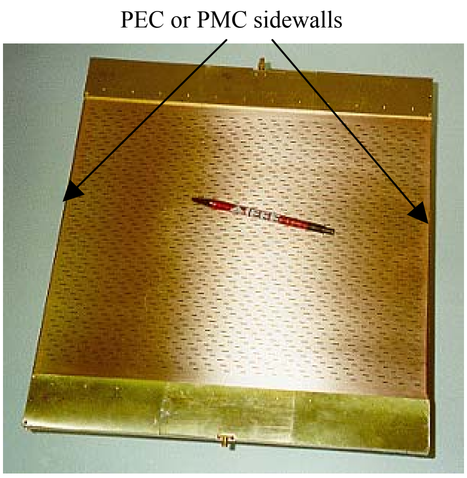

Fig. 14. Parallel plate slot antenna with linear polarization excited by microstrip circuit.

V. CONCLUSIONS

The simulation and experimental analysis effects using EBG sidewalls acting as PMC in a parallel plate waveguide and in parallel plate slot antennas have been presented. The simulation and the experimental results in the parallel plate waveguide show that a fairly uniform field distribution along the transverse direction of it with PMC sidewalls has been obtained. These results demonstrate the feasibility of applying PMC sidewalls to improve the characteristics of parallel plate slot antennas. A most uniformity of the field distributions allow us to increase the directivity, to enhance the efficiency of these kind of antennas. These pratical applications will allows us to validate the simulation results. The analysis results of the effect between the PEC and PMC sidewalls in prototypes of parallel plate waveguide and parallel plate slot antennas will be compared with the simulation results and presented in URSI-COST284 '04.

ACKNOWLEDGEMENT

The authors would like to thank CST (Computer Simulation Technology GmbH) the license for the use of the software CST Microwave Studio v. 5.0, utilized for the simulations that have been achieved in this work.

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